Jet Propulsion Laboratory
California Institute of Technology

WFIRST Coronagraph Pictures for STMD

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August 17, 2017

Outline

1. *Photos of coronagraph components such as masks, deformable mirrors, etc;*
2. *Photos of the TRL-5 demonstration hardware in the JPL High-Contrast Imaging Testbed;*
3. *Photos of the labs where the masks are manufactured;*
4. *Photos of the science and engineering teams who are working on the coronagraph;*
5. *Simulated science images from the WFIRST coronagraph;*
6. *Plots to illustrate WFIRST coronagraph capabilities vs. the current state of the art;*
7. *Artists' concepts of the types of planets that the WFIRST coronagraph is designed to characterize*

1. PHOTOS OF CORONAGRAPH COMPONENTS

1. Photos of coronagraph components such as masks, deformable mirrors, etc

Caption: WFIRST Coronagraph Shaped Pupil Planet Imaging and Spectroscopy
Mask materials are Black silicon and Silver/Aluminum?
Mask is fabricated at JPL's Microdevices Laboratory

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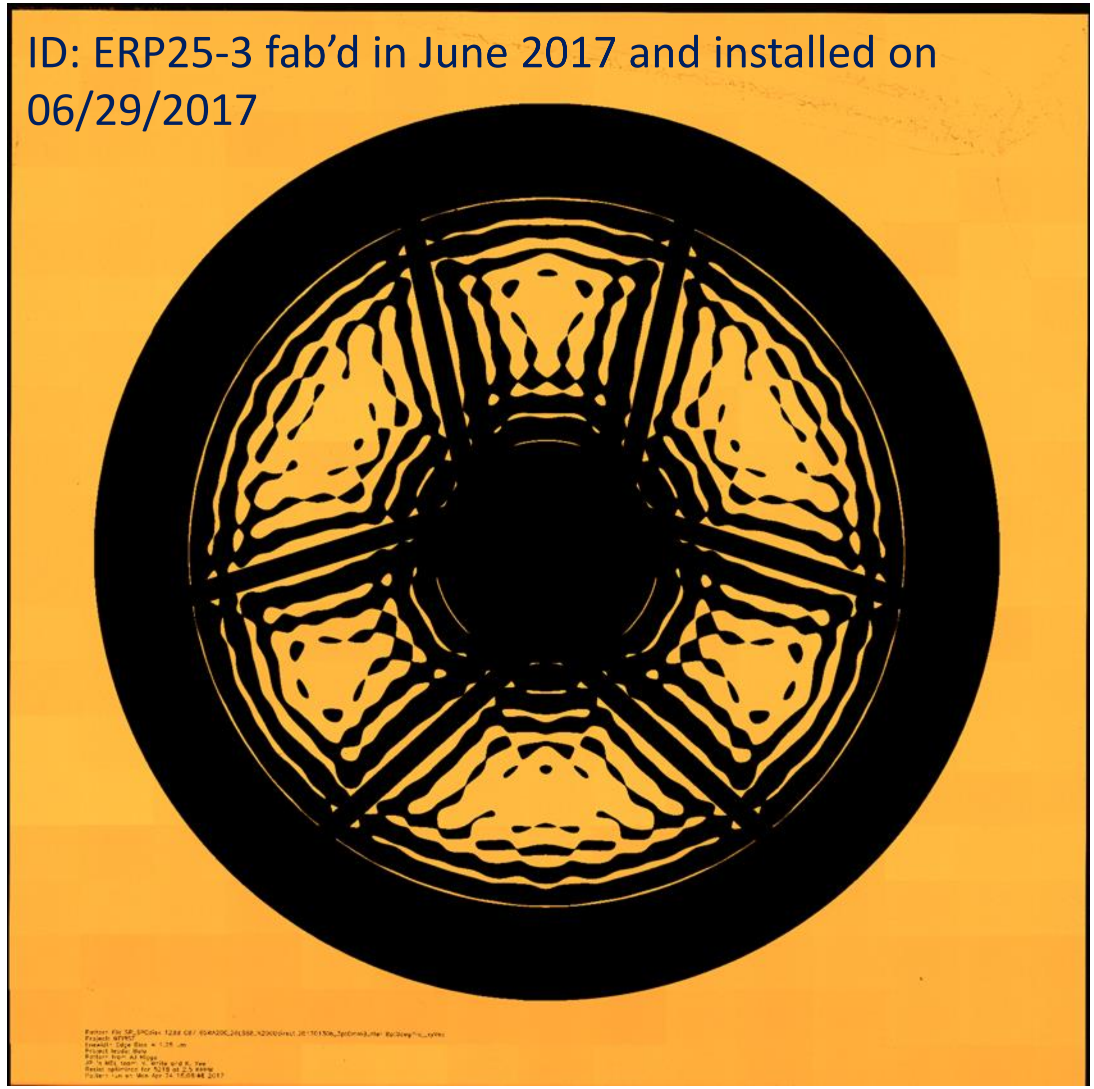
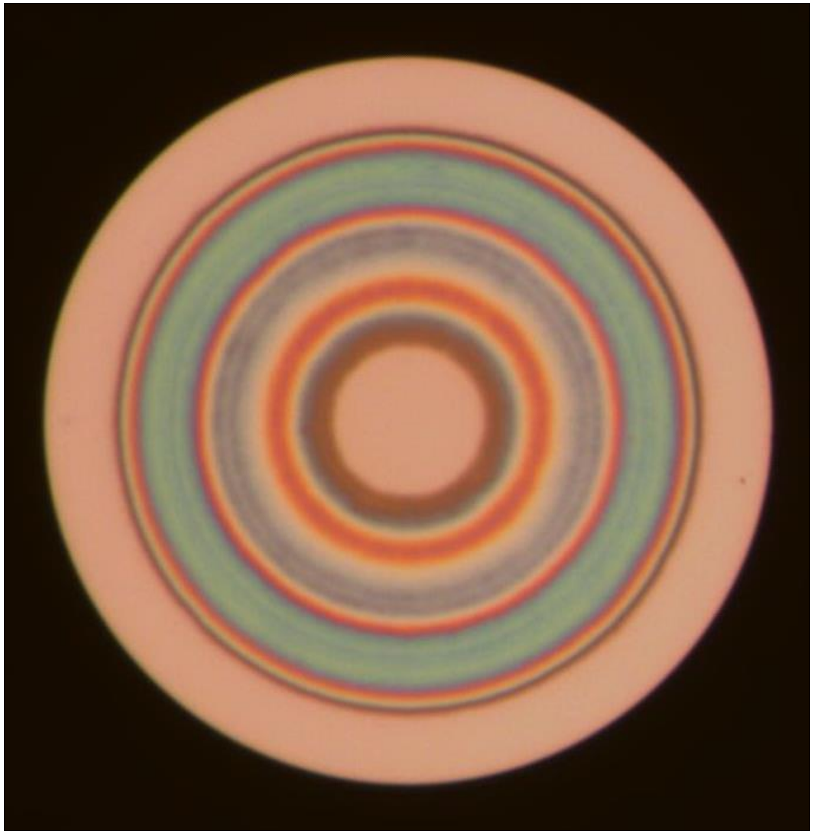
1. Photos of coronagraph components such as masks, deformable mirrors, etc

Caption: WFIRST Coronagraph Shaped Pupil Disk Science Mask in it's Optical Mount



Caption: WFIRST Coronagraph Shaped Pupil Disk Science Mask

1. Photos of coronagraph components such as masks, deformable mirrors, etc



Caption: WFIRST Hybrid Lyot Coronagraph (HLC) Focal Plane Mask

Diameter of the mask is approximately 85 microns!

Masks are nanofabricated at JPL's Microdevices Laboratory

1. Photos of coronagraph components such as masks, deformable mirrors, etc

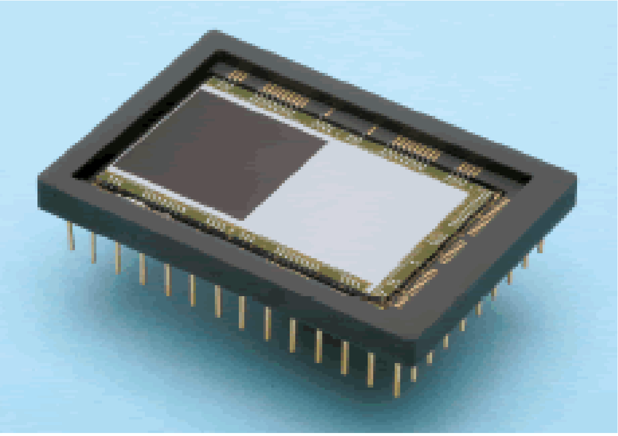
Deformable Mirrors

- 48x48 actuators
- 48 mm diameter active area
- PMN = Lead Magnesium Niobate **$Pb(Mg_{1/3}Nb_{2/3})O_3$**
- Made by Northrup Grumman Xinetics in collaboration with JPL

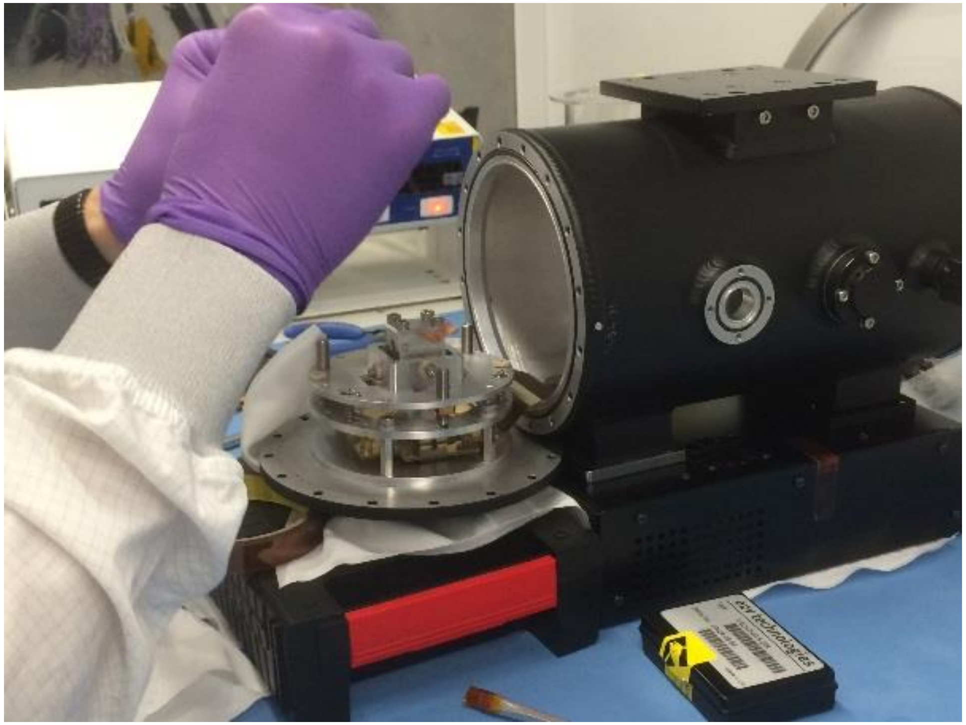
Caption: Deformable Mirror used for WFIRST Coronagraph

1. Photos of coronagraph components such as masks, deformable mirrors, etc

1k x 1k Electron Multiplying CCD (EMCCD)
CCD201-20 by Teledyne e2v
Detectors have passed radiation testing
Will be the first ultra-low noise detectors flown in space



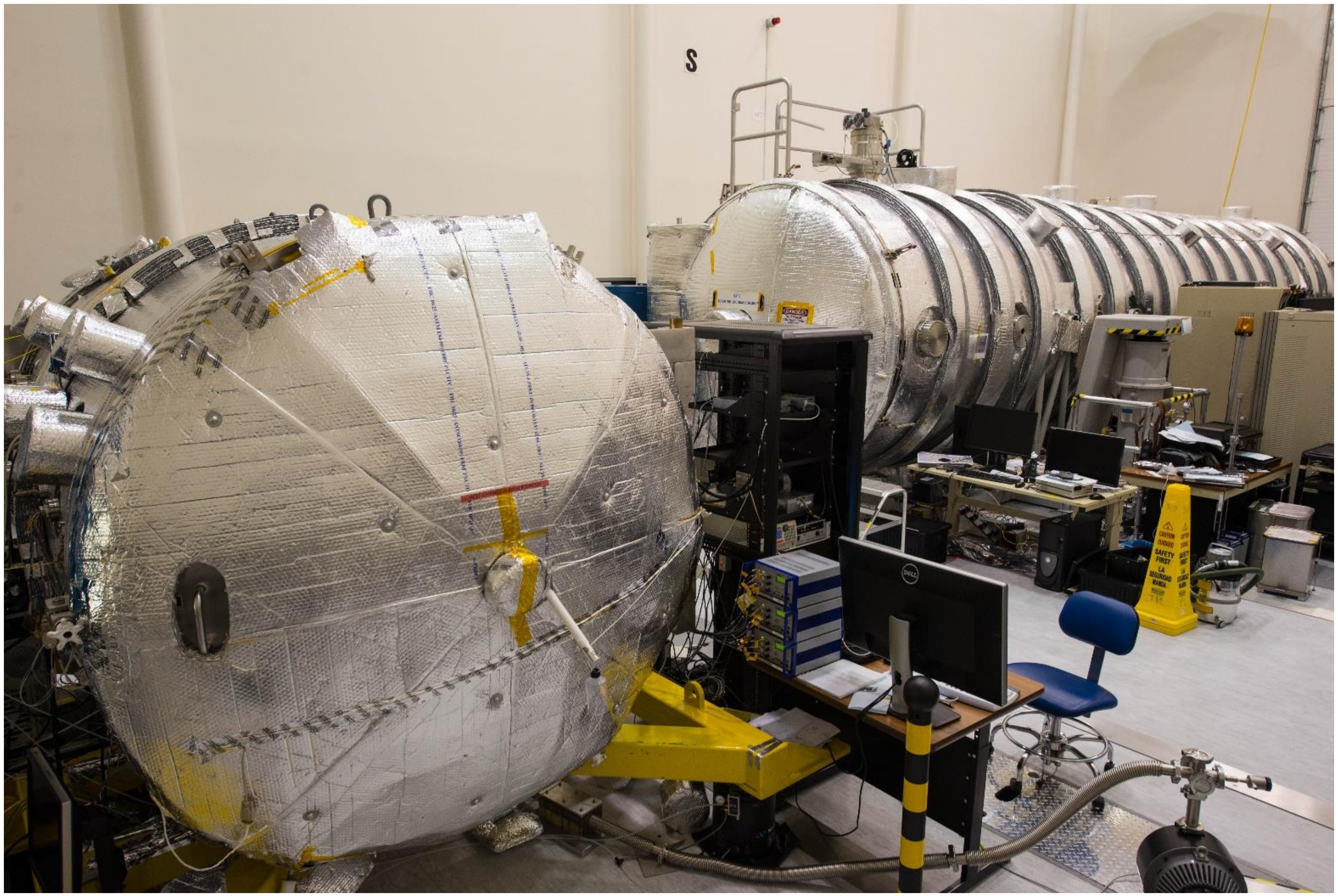
Caption: Performance testing of EMCCD Detector at JPL's Low Flux Detector Laboratory



2. PHOTOS OF THE TRL-5 DEMONSTRATION HARDWARE IN HCIT

2. Photos of the TRL-5 demonstration hardware in the JPL High-Contrast Imaging Testbed

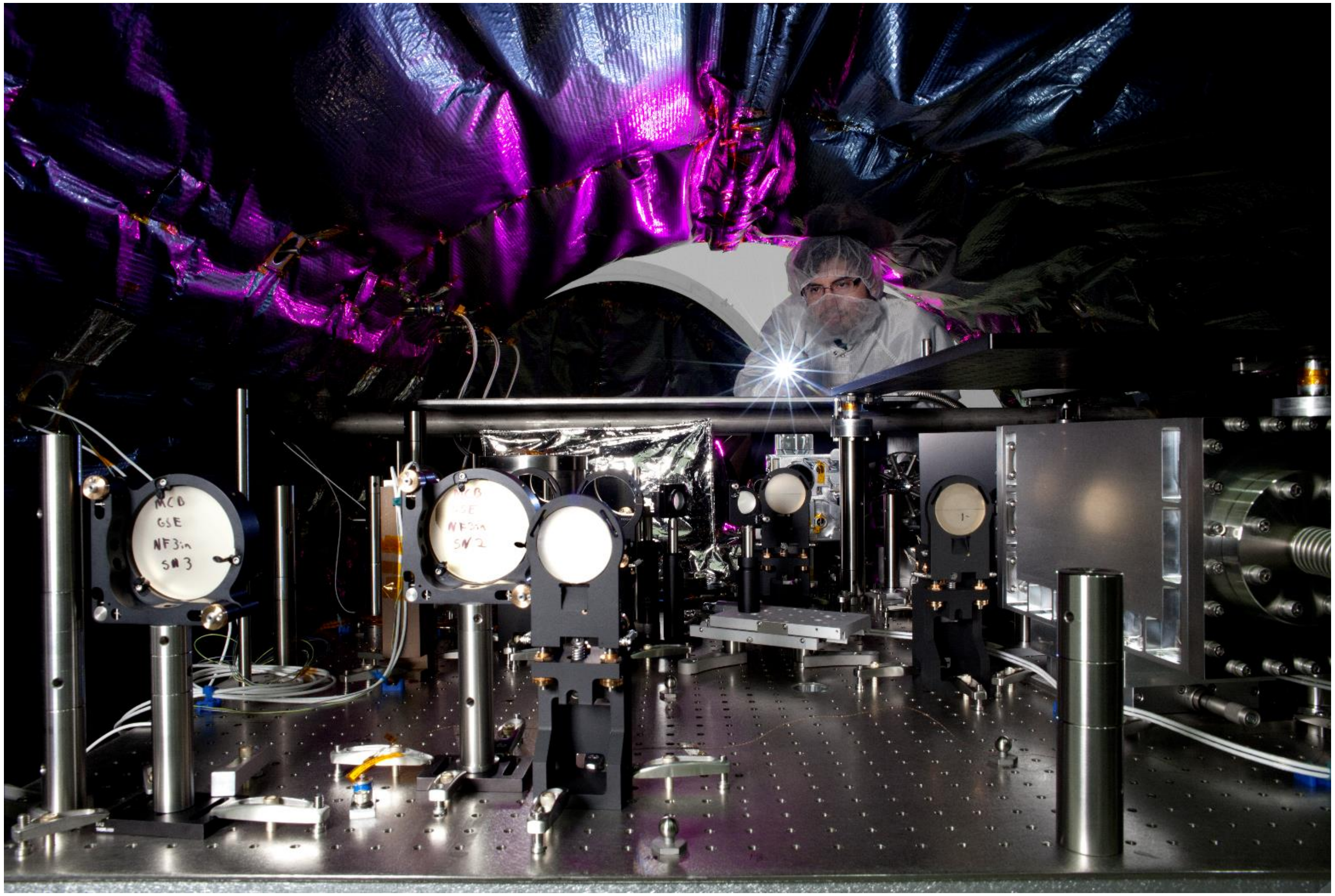
ExEP High Contrast Imaging Testbed (HCIT) Facility



Caption: HCIT-1 (left) is the vacuum chamber at JPL testing the WFIRST coronagraph; HCIT-2 (right) is testing the WFIRST coronagraph spectrometer.

2. Photos of the TRL-5 demonstration hardware in the JPL High-Contrast Imaging Testbed

ExEP High Contrast Imaging Testbed (HCIT) Facility

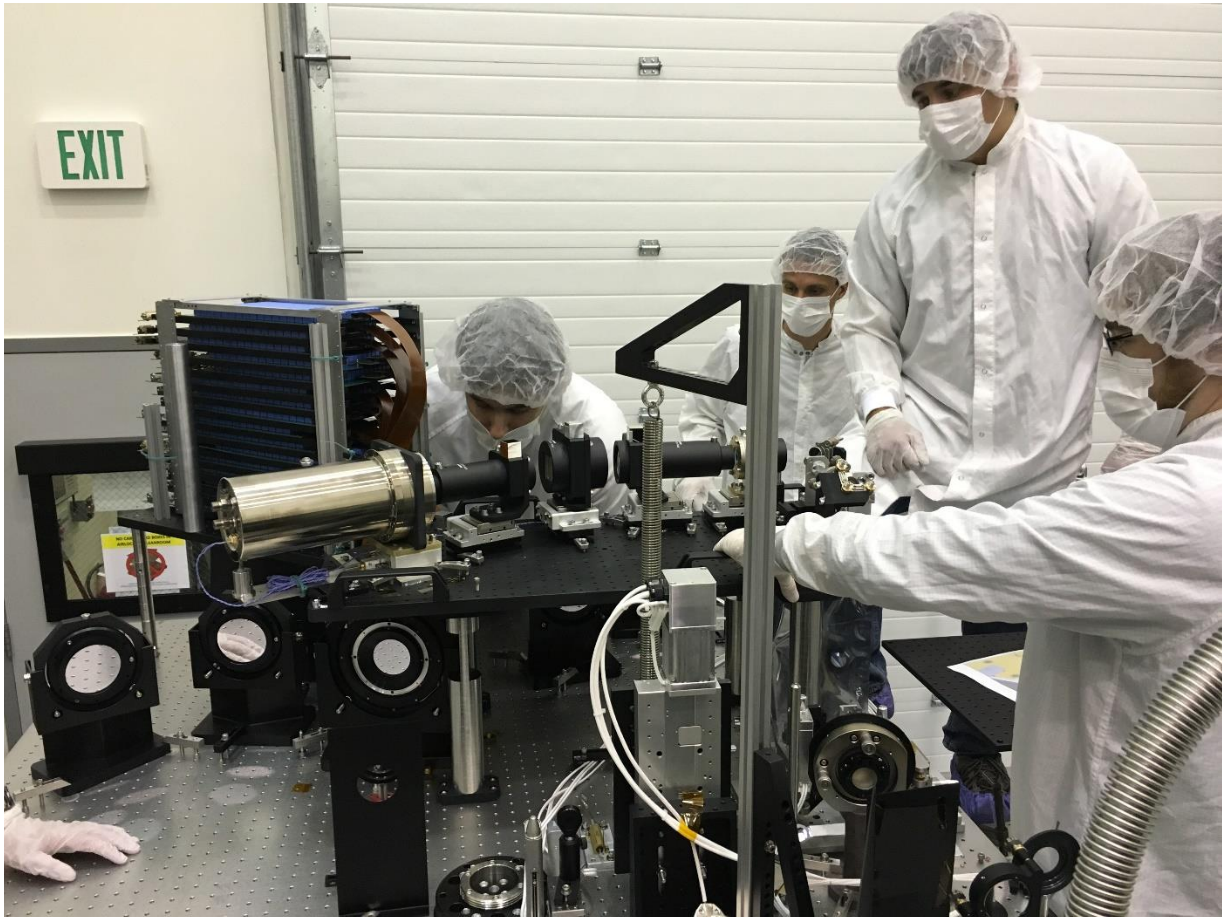


Caption: The WFIRST coronagraph inside a vacuum chamber at JPL.

ExEP High Contrast Imaging Testbed (HCIT) Facility

Caption: The WFIRST Hybrid Lyot coronagraph being placed inside its vacuum chamber at JPL.

ExEP High Contrast Imaging Testbed (HCIT) Facility

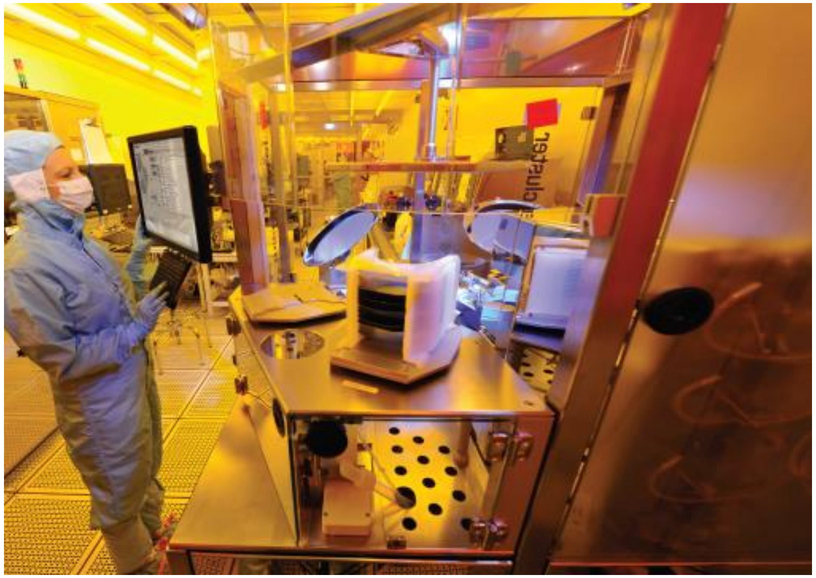


Caption: The Goddard Space Flight Center spectrometer (PISCES) being prepared to be inserted into its vacuum chamber at JPL.

3. PHOTOS OF THE LABS WHERE THE MASKS ARE MANUFACTURED

3. Photos of the labs where the masks are manufactured;

Click for video



Caption: Mask fabrication with e-beam facility at JPL's Microdevices Laboratory

4. PHOTOS OF THE SCIENCE AND ENGINEERING TEAMS WHO ARE WORKING ON THE CORONAGRAPH

4. Photos of the science and engineering teams who are working on the coronagraph

Coronagraph Adjutant Scientist (CAS): Jeremy Kasdin, Princeton University

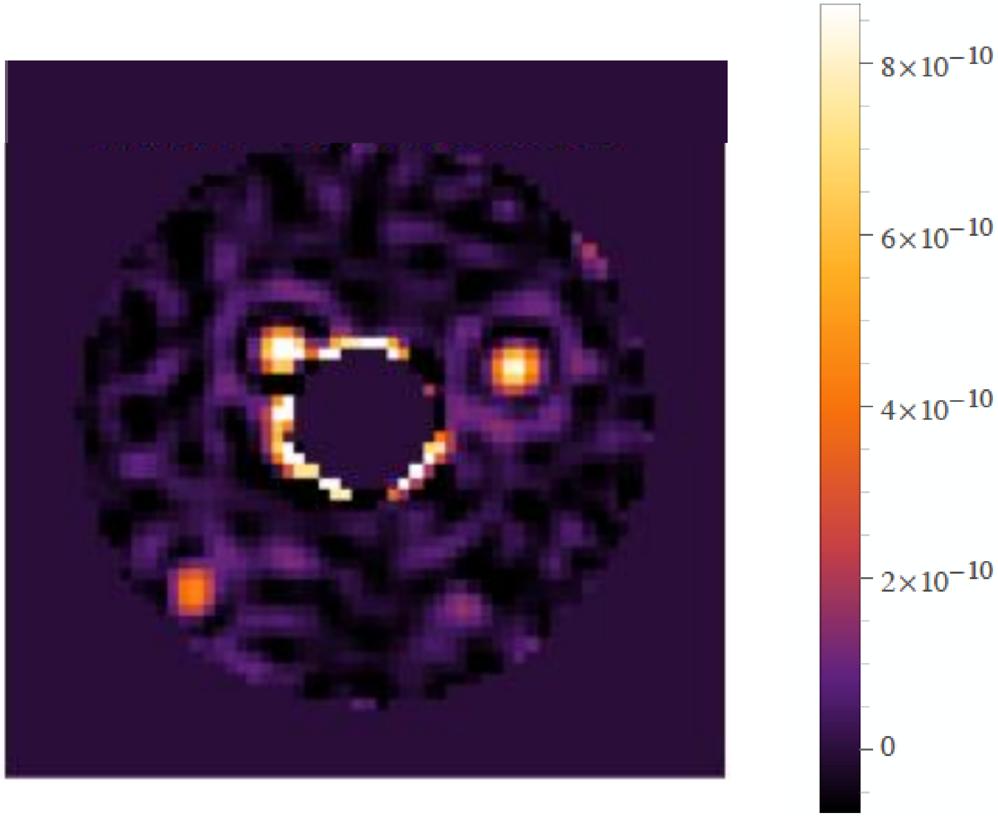
Science Investigations Teams (SIT):

SIT #1 PI: Bruce Macintosh, Stanford University
SIT #2 PI: Maggie Turnbull, SETI Institute

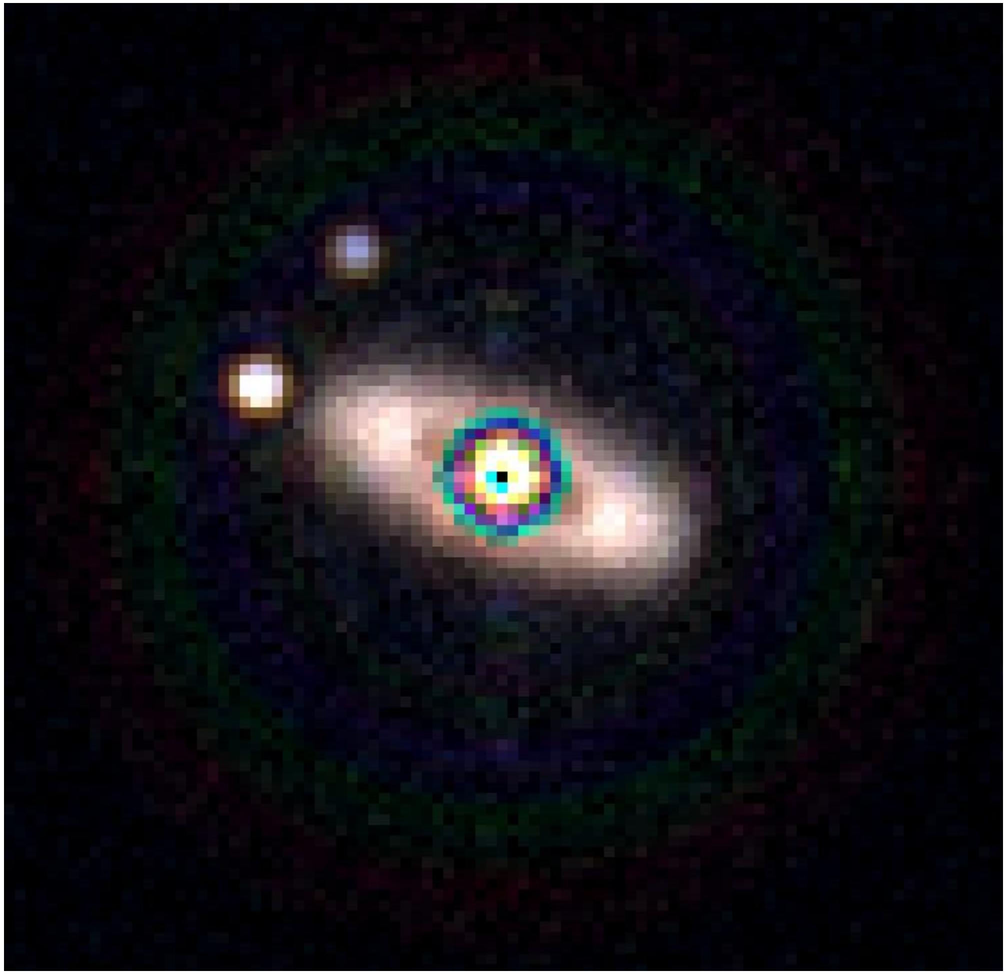
4. Photos of the science and engineering teams who are working on the coronagraph

5. SIMULATED SCIENCE IMAGES FROM THE WFIRST CORONAGRAPH

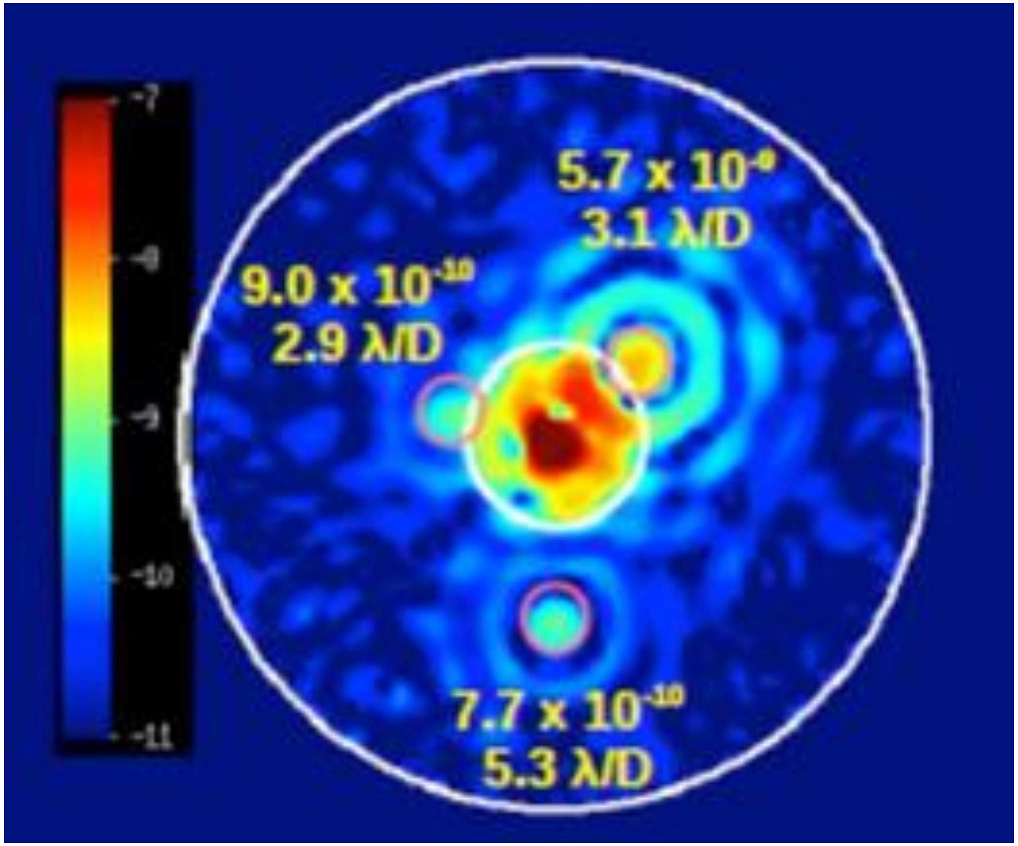
5. Simulated science images from the WFIRST coronagraph



Caption: Simulated image of science target 47 UMa using the WFIRST Hybrid Lyot Coronagraph. A post-processing algorithm, called KLIP, was used to pull the planet signal from the noisy background light.



Caption: Simulated image of 1 zodi circumstellar disk along with two gas giants exoplanets (Jupiter and Staurn analogs). Picture taken from Exo-C STDT final report.



Caption: Simulated image of three gas giants exoplanets using the WFIRST Hybrid Lyot Coronagraph.

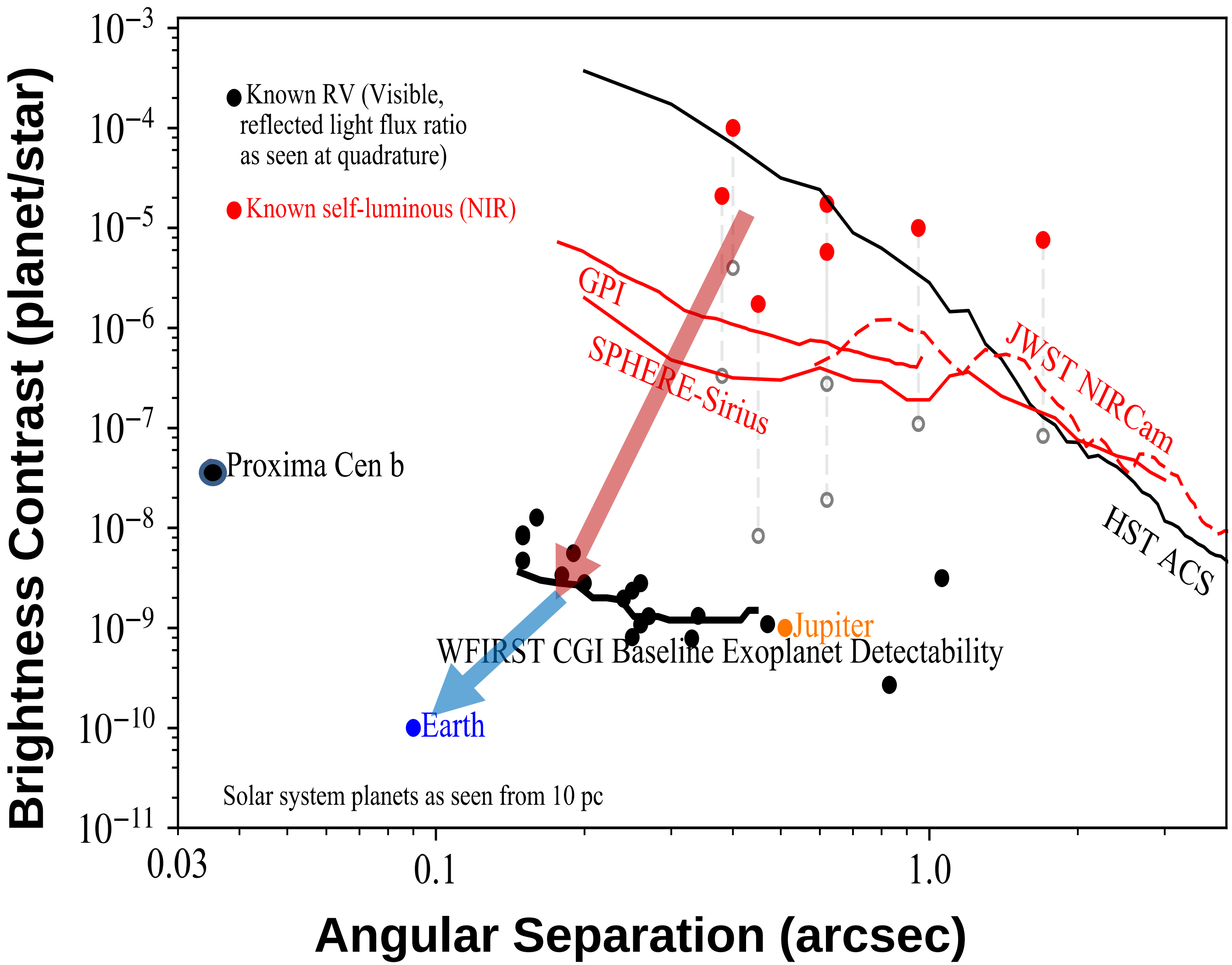
6. PLOTS TO ILLUSTRATE WFIRST CORONAGRAPH CAPABILITIES VS. THE CURRENT STATE OF THE ART

Caption and Notes for the next slide

- Notes:
  - This is the money slide. This chart, if understood, is the reason the WFIRST coronagraph is so important to NASA's search for life effort. It is a key technology stepping stone from the SOA (HST and ground telescopes) to the capability we need to directly image exo-Earths and look for signs of life. WFIRST coronagraph advances the SOA from HST by 4 orders of magnitude and the ground by at least 2 orders. That leaves us 1-2 orders away from the requirements for the next NASA exoplanet mission.

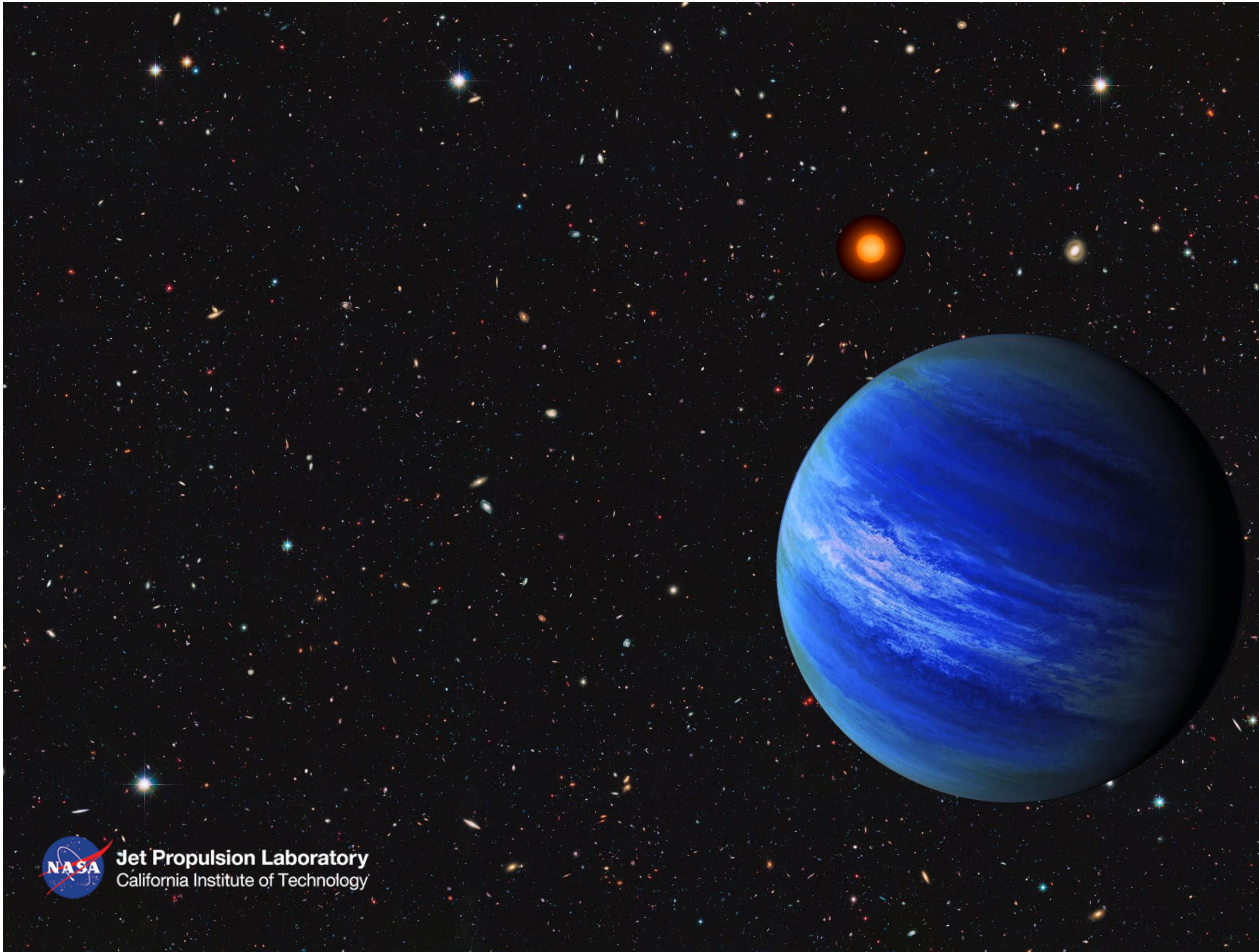
- Caption:
  - Brightness contrast ratio (ratio of planet brightness to host star brightness) versus apparent angular separation. The filled orange circles indicate the direct imaging of young, self-illuminous planets imaged in the near-infrared by ground-based telescopes. Contrast for the Earth point is for analogous exo-Earth placed 10 pc away. The solid black dots are contrast estimates of known radial velocity planets, including Proximus Centauri b, the closest exoplanet to the Earth. The orange curves show measured performance of ground-based coronagraphs: the GPI curve shows typical performance, while the SPHERE curve shows the best achieved performance to-date on the reference star Sirius. Achieved performance with HST/ACS coronagraphic masks, and the predicted performance of JWST/NIRCam masks are also shown. The current best estimate for WFIRST coronagraph (solid back) is at 565 nm and includes a factor of 10 contrast improvement from data post-processing. The WFIRST coronagraph contrast requirement is 3×10^{-9}.

WFIRST Coronagraph, A key stepping stone



7. ARTISTS’ CONCEPTS OF THE TYPES OF PLANETS THAT THE CGI IS DESIGNED TO CHARACTERIZE

7. Artists' concepts of the types of planets that the WFIRST coronagraph is designed to characterize



Artist’s conception of extrasolar Saturn-like planet, in the early stages of forming a ring

Exoplanet GJ 1214b is a super-earth covered with high-altitude clouds .gov

Exoplanet Kepler 186f is ~1.4 x Mass of earth.
WFIRST CGI cannot image but is enabling technology to image earth-like exoplanets.